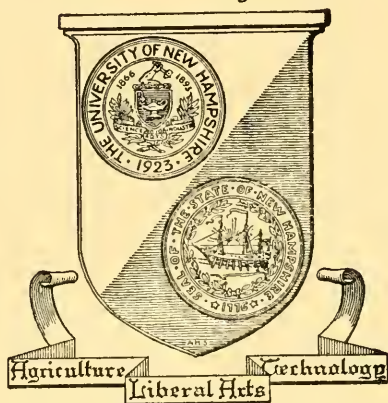


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STUDIES IN ECONOMICS OF APPLE ORCHARDING

IV. Spray Management

By

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SUMMARY

1. In general, at least five sprays are needed to secure good fruit.
2. Thoroughness and timeliness of application, especially good coverage of the tops of the trees, are important in securing good control of diseases and insects.
3. Efficiency of man labor and machine operations are important in spraying, but often the most essential thing is to cover the orchard within a definite time even though the cost may be increased.
4. An adequate supply of water, easily and quickly available, is an important factor in efficient spraying.
5. The cost of spraying is a small part of the total cost of apple production, and good fruit is so essential to success that the five standard sprays should be applied normally. If the equipment and labor are available, the out-of-pocket cost of an additional (marginal) spray is very small.
6. The medium-sized spray outfit seems most efficient for small orchards or those with rough topography.

SPRAY MANAGEMENT

By Harry C. Woodworth and Cecil O. Rawlings

THE APPLICATION OF SPRAYS to control the pests of apples is the orchardist's most difficult management problem. Effective control requires the thorough covering of all the trees within very brief and definite periods of time. Since insects and diseases must be destroyed at certain definite stages in their development, changing weather conditions may either hasten or delay the effective spraying so that only a fraction of the control period is available for the operation.

Under these conditions the operator must have expensive equipment in good repair and skilled labor available for efficient operation to cover the trees within the effective period and when weather is favorable. In certain years this may mean only an hour or so a day. Equipment of sufficient capacity to cover the orchard quickly will not be used many days a year, yet adequate equipment is essential. In order to have skilled labor available for these brief but definite periods, a plan for its utilization productively in non-spray periods is often necessary. (*See spray time schedules, Figures 9 to 12.*) Often the operator can use his own time to advantage in orchard work for most of the year, but there are periods during the season when it is difficult to employ the extra spray help to advantage. Yet such help will not be available at critical spray periods if the men are not employed full time.

On account of the need for the expensive equipment and the skilled help for short periods, the spray practice is one of the chief factors in determining the most economical and practical size of orchard unit. Efficiency and effective management procedure in connection with spraying will enable the individual grower to handle a larger orchard. For these reasons spray management is far more important than is indicated by hours of man labor and cost per hour of equipment. It is the crux of the whole field of orchard management.

This project of studying in detail the management problems associated with spraying was undertaken in order to guide orchardists in their practices in this critical operation. Fifty farmers were selected as co-operators; for two or more years 40 of them kept detailed spray records, representing a total of 158 orchard years. The orchards were mapped, inventories of equipment and supplies were taken, and the operators were instructed in the keeping of spray records.

Description of the farms

The 40 farms include a wide range in size of orchards from several part-time enterprises of 200 to 400 trees to large specialized apple farms

¹This project was initiated as a joint project with the Departments of Agricultural Economics and of Horticulture co-operating. The field work was undertaken by E. J. Rasmussen, at the time a member of the Department of Horticulture. H. C. Woodworth, G. F. Potter, and C. O. Rawlings co-operated in certain phases of the work. Mr. Rasmussen and Mr. Potter resigned to take positions elsewhere. Mr. Woodworth and Mr. Rawlings completed the field work and made the analysis.

with several thousand trees. Also several types of management were included. While the farms were selected on the basis of individual operators who were willing to co-operate by keeping records, it is thought that the 40 farms are fairly representative of the commercial industry.

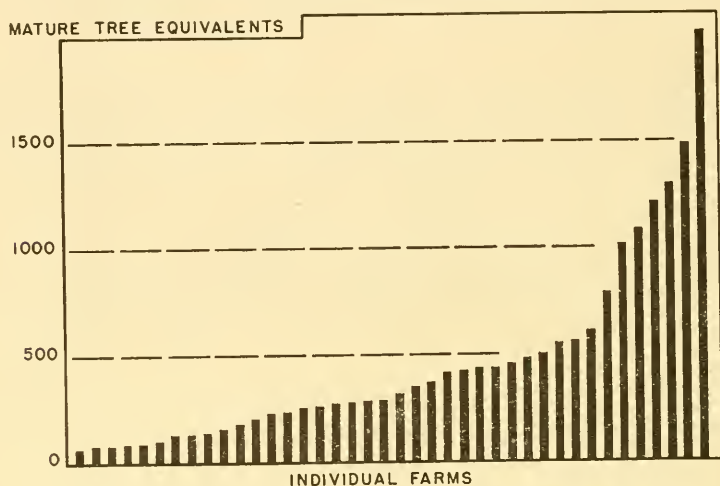


Figure 1.—Distribution of farms by mature tree equivalent

Figure 1 indicates the distribution of the 40 orchards according to size, as measured by mature-tree equivalent¹. Based on the normal yield curve determined in an earlier study the expected yield for the 40 orchards, in 1932, was 132,632 bushels and on individual farms the yield ranged from 402 to 10608 bushels. This gives an approximate measure of the size of the enterprises. (Figure 2.)

Comparison of actual and expected yield

The yields expected by the operator are important in spraying operations, and orchardists sometimes adjust their practices, especially the late sprays if the crop is small. On 27 farms representing 82 orchard crop years, records were available for comparison of the expected yield as measured by the normal yield curve and the actual yield. The actual yields for the period were 15 per cent above expected yields or 312,292 boxes of commercial apples as compared to the expected yield of 271,607 boxes.

Since the normal curve was constructed on the basis of a six-bushel yield on mature trees the actual yield on these orchards averaged 6.9 bushels. The average yields on nine farms were below the normal yield and nine farms were 50 per cent or more above. The ratio of the average actual yields to expected yields on individual farms ranged from 55 to 290 per cent. (See Figure 3.)

Individual orchards fluctuated greatly from year to year. For instance, on one orchard, yields were 239, 64, 109, and 34 per cent of

¹Bulletin 257 — Studies in Economics of Apple Orchardling by H. C. Woodworth and G. F. Potter.

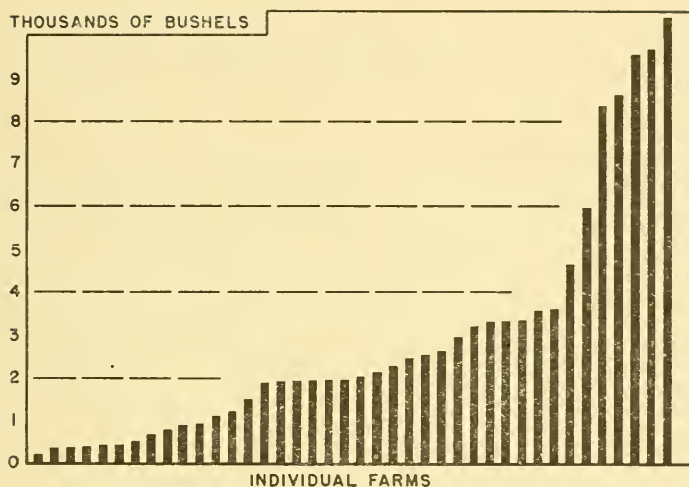


Figure 2.—Distribution of orchards according to expected normal crop

normal respectively for four years. Another orchard yielded 87, 371, 69, and 133 per cent of normal. Several orchards were constantly low in yield; for example, one operator reported yields that were 35, 60, 41, and 48 per cent of normal. On the other hand, one small orchard had yields of 170, 165, 360, and 199 per cent. The lowest yield reported for any one year was 19 per cent of normal and the highest 371 per cent.

No doubt this variation in yield is an important factor in accounting for variations in spray practices on the same farm in different years and between individual farms in the same year. Naturally, the operator with a prospective large crop can afford to spend more material and labor per tree. The cost per bushel of an additional spray would be in-

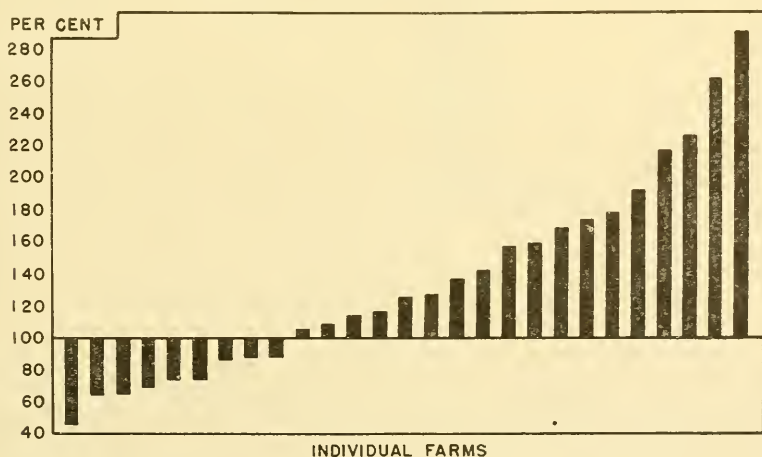


Figure 3.—Distribution of 27 individual orchards according to percentage of average actual yields to normal expected yield

significant. In comparison, the operator with only 35 per cent normal crop has to reason more carefully because the cost of extra sprays or additional control that year would be high per box of apples.

Large and small orchards

The management problem in spraying varies with the size of the enterprise. On large farms the orchardist has to press the utilization of equipment and available men to the limit at certain periods to cover the trees within the proper time. Often the spraying will continue to late hours or all night to take advantage of favorable weather. On small farms the equipment can cover the orchard in a short period but the operator may have difficulty in getting extra help when he needs it. The small operators who have learned to spray alone or with the assistance of unskilled or family help have partially solved these spray management problems.

Control

In order to appraise the results of spray applications, a control rating was estimated for each farm. This rating was made by the fruit specialist² and was based on records of inspection made each fall just prior to harvest and on observations made as to degree of control of insect and diseases during the five-year period. The ratings represent the specialist's estimate of the relative control situation on each farm during the period of study. Thus a 92 control rating in this study means that approximately 92 per cent of the apples were free of such injury.

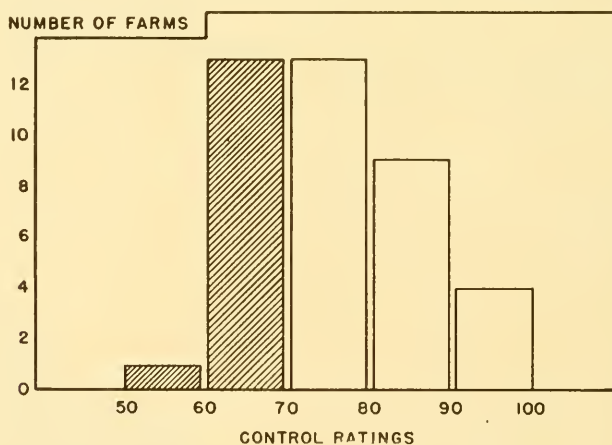


Figure 4.—Distribution of 40 farms according to control ratings

These control ratings are thought to be good workable measures of the control in each orchard. Four of the 40 farms were rated 90 or above and classified as obtaining excellent control. Nine were rated between 80 and 90 and classified as having very good control. Thirteen were

²C. O. Rawlings, Extension Horticulturist.

assigned a rating between 70 and 80 and were classified as having good control. Of the remaining 14 farms, 13 were given ratings between 60 and 70 or fair control and one a rating of under 60 and classified as having poor control.

The 26 farms which obtained excellent, very good, or good control were considered to have commercial control. To be sure, some of these had fruit of a poorer quality than others, but by careful grading most of the apples could be sold commercially under a definite grade. The 14 farms which obtained fair and poor control were considered as having obtained less than satisfactory commercial control. These farms are failing at some point in their application of sprays.

Number of sprays and control

The records available from the 40 farms represented 158 orchard spray years. Five, six, and four sprays per season were the most common applications in the order named. Only 5 per cent of the records indicated less than four applications and only 10 per cent, more than six applications. Two applications was the lowest number and 11, the largest.

There was some variation from year to year in the same orchards. The amount of fruit on the trees, the prevalence of pests and disease, and the weather conditions were important factors in the operators' decision as to number of sprays. The 158 spray season records indicate the number and kind of sprays applied as follows:

Calyx	158
Pink	153
1st Cover	149
Pre-Pink	148
2nd Cover	106
Delayed Dormant	39
3rd Cover	37
4th Cover	3
Early Pink	2
5th Cover	1
Other	49

All orchardists applied the calyx spray every season. Only five of the 158 spray records show elimination of pink spray. The first cover was omitted in only nine instances, the pre-pink only 10 times. None of the operators omitted the pink or pre-pink more than one year, but on one farm the first cover was not applied in any year. Twenty-six operators, or 65 per cent, applied the four most common sprays, the pre-pink, the pink, the calyx, and the first cover every year. Thus the four sprays, calyx, pink, first cover, and pre-pink, were generally applied. The other standard or special sprays were not applied universally. The second cover was applied in about two-thirds of the cases recorded and the dormant spray and the third cover in about one-fourth of them. The other special sprays were applied in only a few instances.

When the average number of sprays is compared to the control ratings for each orchard the correlation is not high but operators making frequent applications do tend to have greater control. One orchard which averaged only four sprays had a high rating and a few orchards

with as many as six applications had low ratings. None of the six orchards with an average of nine applications had ratings over 90 although none was under 70.

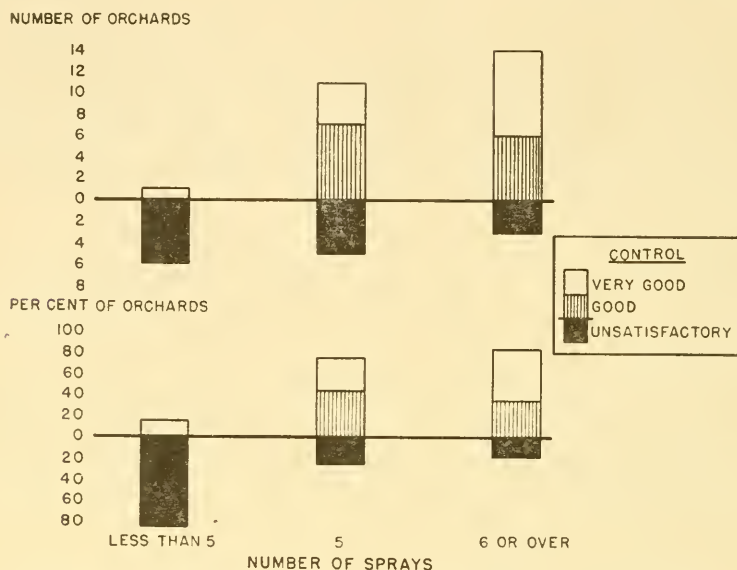


Figure 5.—Control ratings of orchards applying varying number of sprays per season

However, when the farms were divided into three groups according to the average number of sprays applied, six out of seven orchards with less than five applications had unsatisfactory commercial control, five out of 16 orchards with an average of five sprays, three out of 17 with six or more applications had unsatisfactory commercial control. (Figure 5.) These data show a tendency for the group of orchards with fewer number of spray covers to have higher proportions of orchards with unsatisfactory commercial control. It is significant that 83 per cent of the operators in the group applying a small number of applications had unsatisfactory control as compared to 25 per cent and 18 per cent in the groups making more numerous applications. On the other hand, the data indicate that high control depends on additional factors. The data in Figure 5 indicate a considerable dispersion in control with the same number of sprays³. From observations in the field it is thought that the orchardists who apply a large number of sprays and yet do not get good results are not careful in getting spray material to the top of the trees and in covering other parts thoroughly.

Gallons of spray applied and control

The amount of spray applied per mature-tree equivalent varied from 8 to 67 gallons. Eleven of the 40 farmers applied less than 20 gallons,

³The coefficient of correlation between average number of sprays and control rating is: $r = .39$.

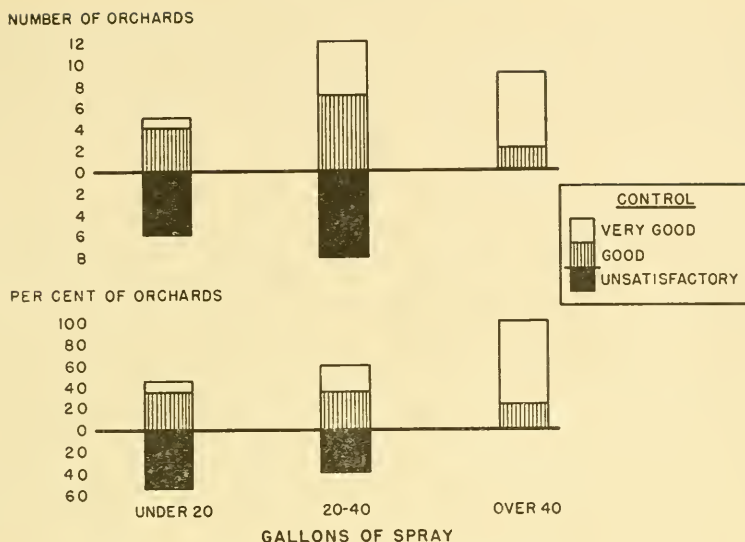


Figure 6.—Control ratings of 40 orchards applying varying amounts of spray per season

20 applied between 20 and 40 gallons and nine used more than 40 gallons. (Figure 6.) Fifty-five per cent of those who applied less than 20 gallons and 40 per cent of those who applied between 20 and 40 gallons obtained unsatisfactory control. While a higher percentage of those using small applications failed to get satisfactory control, a few operators in this group obtained good results. The amount of spray used and the

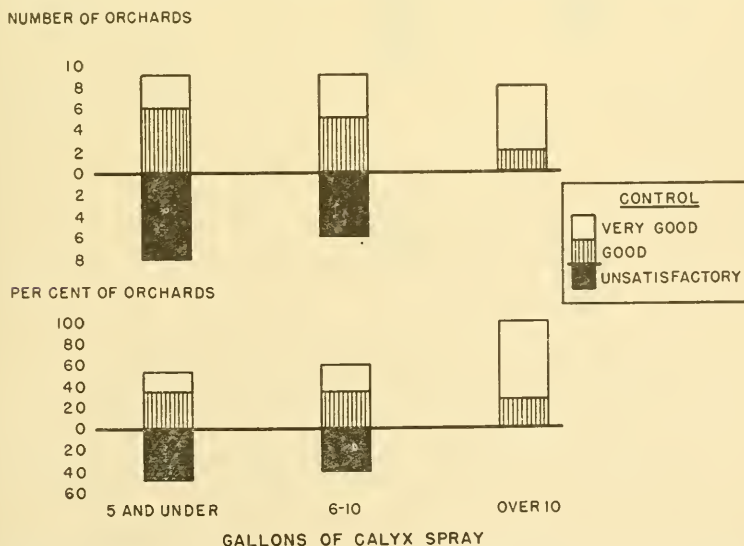


Figure 7.—Control ratings of 40 orchards applying varying amounts of calyx spray per season

number of sprays are related and the conclusions are similar. The percentage of farms having unsatisfactory control was greater in the group with small application of spray material. The data in *Figure 6* indicate the position of individual orchards as to gallons of spray and control ratings⁴.

Amount of calyx spray and control

Since all operators apply the calyx to all trees every season, the amount of spray applied at this time is thought to be a good measure of the practice on each farm as to the amount of material applied in one spray application. Seventeen operators applied five gallons or less per mature-tree equivalent, 15 applied between six and 10 gallons, and eight used more than 10 gallons. Forty-seven per cent of those applying less than five gallons, 40 per cent of those applying between six and 10 gallons, and none of those applying more than 10 gallons had unsatisfactory control. However, three orchardists applying less than five gallons obtained excellent control. On the other hand, six of those applying between six and 10 gallons had unsatisfactory control. In *Figure 7* the position of individual farms with respect to amount of calyx applied and control ratings is indicated⁵.

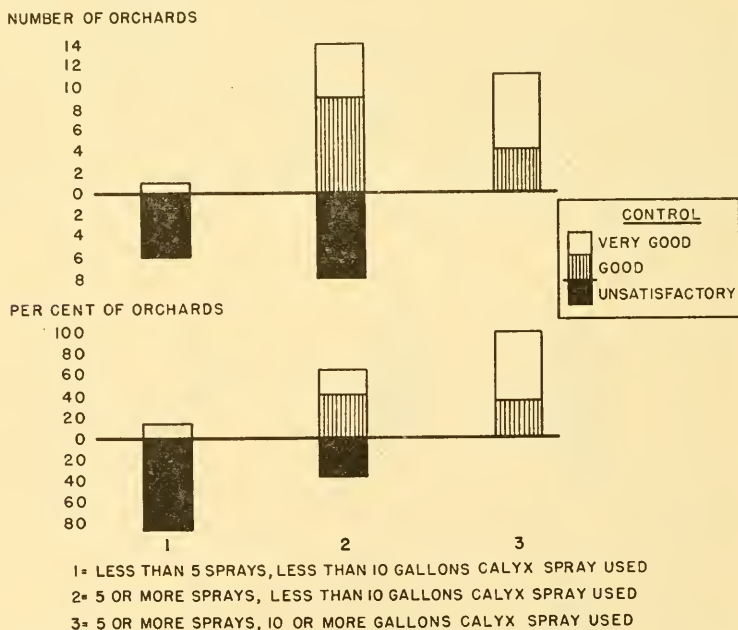


Figure 8.—Control ratings of 40 orchards applying varying numbers of sprays and varying amounts of calyx spray per season

⁴The coefficient of correlation between gallons of spray applied per mature-tree equivalent during the season and control ratings is: $r = .57$.

⁵The coefficient of correlation between gallons of calyx spray per mature-tree equivalent and control ratings is: $r = .54$.

Number of sprays and amount of calyx spray and control

So far the number of sprays, the amount of total spray material, and the amount of calyx spray have been related to control independently and without regard to relationship. The combination of number of sprays and the amount of material applied in the calyx application is noted here⁶. (*Figure 8*.)

The orchards were divided into three groups. In group 1, consisting of seven orchards with few applications and small amounts of material at each application, 86 per cent of those orchards secured unsatisfactory control. In group 2, consisting of 22 orchards with more than five applications but with small amount of material each time, 36 per cent of the orchards obtained unsatisfactory control. All 11 farms in group 3 were covered with more than five sprays and over 10 gallons of spray material at each application and all had satisfactory control.

The statistical data indicate that numerous heavy applications tend to result in satisfactory control. Yet a few orchardists secure control with five or six sprays and moderate applications each time, and a few others, who apply the usual standard sprays and use moderate to heavy applications, do not get very good control.

Skill and timeliness

The data indicate that other factors in addition to number of sprays and gallons of material are involved in control. Evidently, skill in application and timeliness are important factors. The spray records, supplemented by observations of the fieldmen, indicate that the skill of the operator in applying the material so as to cover all parts of the tree and the timeliness of the applications are important factors in successful control. The number of sprays and the gallons applied describe only part of the operation. The material must be applied at the right time and the entire foliage must be covered for satisfactory results. For instance, the fieldman observed that several orchardists failed to cover the tops of the trees. In other cases, unfavorable weather conditions limited the time available for the application of a definite spray. Some of the operators, through experience, are able to make an adequate cover even if the weather is not ideal. One operator reported that a wind came up which handicapped the spray operation but because of the limited time available he continued. In a few days, when conditions were favorable, part of the orchard inadequately sprayed was covered again. In a few weeks it was evident that the part of the orchard which had not been re-sprayed had a great deal of scab. This is one example of need of a timely and adequate cover, and shows the inadequacy of depending on the number of sprays or gallons of spray to obtain control.

Skill in management and in application are highly essential

It may be significant that some of the operators who secured very good control did not have trees over 30 years of age. Control in young vigorous orchards is more easily obtained. This is an important factor in determining the commercial age limit of an orchard.

⁶Dr. G. N. Bauer, using the detailed data from the 40 farms, computed an equation of estimate $X_1 = 43.0 + 3.9 X_2 + 1.55 X_3 + 7.6$. Where X_1 = control ratings, X_2 = number of sprays and X_3 = gallons of calyx spray per mature tree equivalent. The coefficient of multiple correlation was found to be $R_{1.23} = .65$.

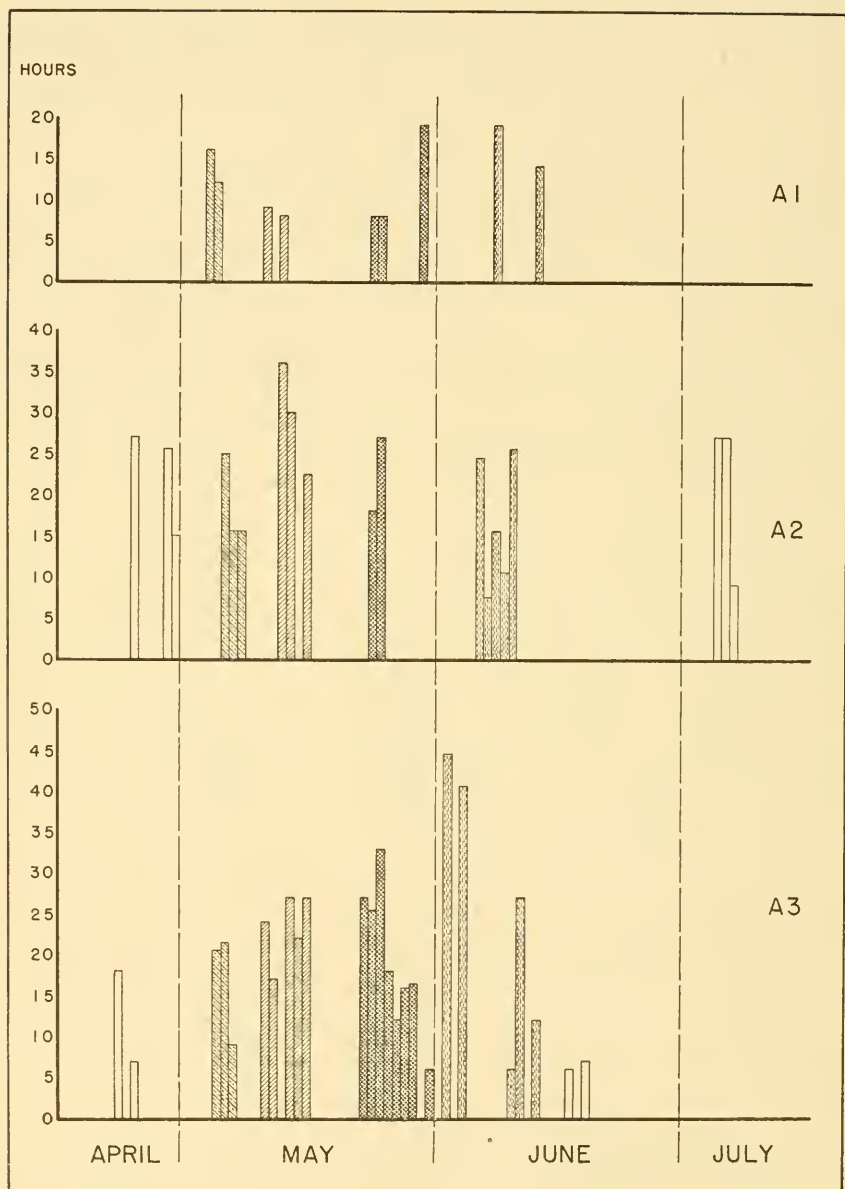


Figure 9.—Seasonal spray schedules on three farms which obtained excellent control

EXCELLENT CONTROL

The three-time schedules in *Figure 9* represent the spray program on three farms, in 1932, where excellent control was obtained. One farm applied four sprays and the other two put on six sprays, including a delayed dormant. One operator covered only part of the orchard for the first and last spray. A close study of the three schedules reveals some variation in the time and pattern of application.

Orchard A1 consisted of a mixed-age orchard with few trees over 25 years. In 1932, the 802 trees were equivalent to only 133 mature trees and the normal expected yield was 903 bushels. The land is rolling and the site is favorable for spraying. The operator used a semi-homemade outfit with a 125-gallon tank and a pump capacity of six to eight gallons per minute. An old long spray rod and nozzle and 50 feet of hose were used. The water was obtained from a one-inch hose attached to the farm water supply system. A team and two men were employed in the operation.

In applying the four sprays, 60 hours were required to put on the 5875 gallons. This is approximately 98 gallons per machine hour and 49 gallons per man hour. The rate of application per hour and the amount applied were greater in the calyx and first cover sprays. This operator, working with mostly young trees, had excellent control with only four sprays and a total application of 45 gallons per mature tree equivalent or 6.2 gallons per bushel of apples.

Orchard A2 consists of 962 trees equivalent to 441 mature trees, in 1932. The expected normal yield was 3210 bushels. McIntosh made up about three-fifths of the orchard.

A 200-gallon tank, with 10-gallon-per-minute pump capacity, was used to apply 20,200 gallons of spray in 134½ hours. A team and a three-man crew were used. The material was applied at the average rate of 150 gallons per machine hour and 50 gallons per man hour. Including the delayed dormant, six sprays were used. With the exception of the first cover, each spray was applied within a three-day period.

Orchard A3 is a larger orchard of approximately 4700 young bearing trees, in 1932. They represented the equivalent of 1026 mature trees and an expected normal yield of 5974 bushels. A large 300-gallon outfit and a crew of three men applied 40,350 gallons of spray in 188¼ hours.

To summarize, a moderate amount of material and the usual amount of sprays were applied on these three orchards. The operators were careful to cover the entire tree. However, all three orchards consisted of young trees, with tops easily reached with spray. There were few trees over 25 years of age and this may be very important in the prob-

Table 1—Data on Orchardists A1, A2, A3 for 1932

No.	Mature Tree Equivalents	Size of Sprayer (Gallons)	Gallons of Spray	Season Machine Hours	Calyx Machine Hours	Spray Material Cost (Dollars)
A1	132.8	100	5875	59	17.5	35.03
A2	441.0	200	20200	134.5	15	148.99
A3	1025.8	250 and 300	40350	188.25	16	437.81

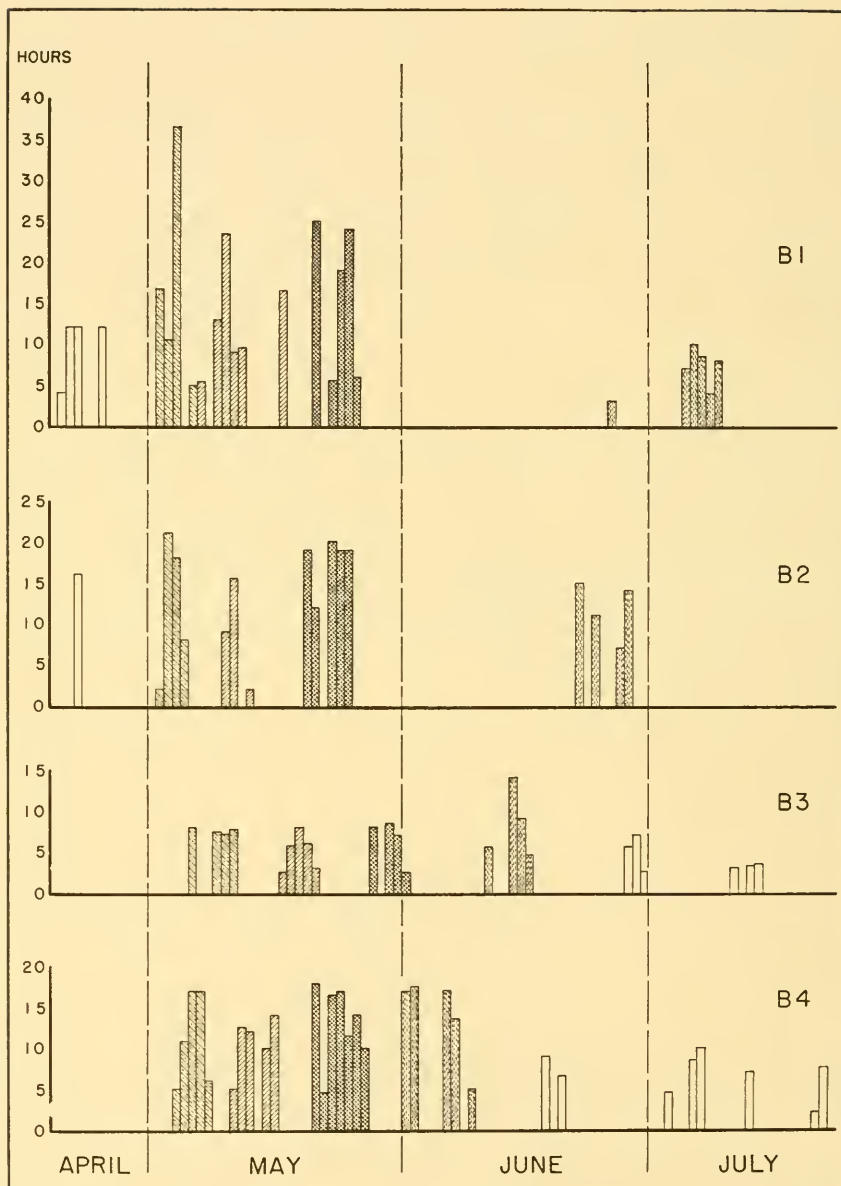


Figure 10.—Seasonal spray schedules on four farms which obtained very good control

lem of control. The age of the trees and the thoroughness of application are thought to be the most important factors in obtaining excellent control in these orchards.

VERY GOOD CONTROL

The four spray schedules illustrated in *Figure 10* indicate the spray programs on individual farms that obtained very good control. The operators applied the usual major sprays and, in addition, two applied delayed dormant and two an additional cover spray.

On farm B1 a large 400-gallon tractor-drawn tank was used. The usual practice was to operate with a two-man crew, but three men were used on one spray. The 23,047 gallons were applied in 138¾ hours employing 305¾ man hours. Almost 50 gallons of spray were applied per mature tree equivalent or about four gallons per bushel of apples.

This orchard of 1819 trees consisted largely of young, bearing apple trees but 130 were over 30 years old. In this orchard a heavy application of the major sprays was put on with considerable skill but, while very good control was obtained, there was some loss from scab and pests.

Farm B2 consisted largely of young bearing trees but also had a number of over 30- and 40-year-old trees. The 28,200 gallons were applied in 117 hours with the use of a 300-gallon, horse-drawn tank and a two-man crew. However, a three-man crew was used occasionally. Six very heavy applications, totalling 65.8 gallons of spray per mature tree equivalent, were used. Two hundred and forty-one gallons were applied per hour. Part of the orchard was on a side hill. The control in the blocks of young trees was excellent and as good as the group illustrated in *Figure 9*. However, in the case of the older trees, scab developed in the tops each year. The operator sprayed from the ground and did not get sufficient spray into the tops of the big trees.

Farm B3 consisted of 1954 trees or what was equivalent to 556 mature trees. The expected yield for 1933 was 3569 bushels and the actual yield 3,080 bushels. The original orchard consisting of trees approximately 25 years of age had been expanded by more recent plantings. A few trees, mostly along the fence rows, were over 45 years old. The 10,350 gallons were applied in 133½ hours by means of a one-man crew and a 100-gallon tank. Only 18.6 gallons were applied per mature tree equivalent which is less than one-third the amount used on farm B2.

Thus, this operator secures very good control with six light sprays which he applies by means of a small machine alone.

Farm B4 is a large orchard with an expected yield of 10,410 bushels. All but 20 of the trees were under 25 years of age. The sprays were applied in 163 hours, including 31 hours of dusting by a large machine.

Table 2—Data on Orchardists B1, B2, B3 for 1932

No.	Mature Tree Equivalents	Size of Sprayer (Gallons)	Gallons of Spray	Season Machine Hours	Calyx Machine Hours	Spray Material Cost (Dollars)
B1	465.7	300	23047	138.75	35.75	240.31
B2	428.5	300	28200	117	47	214.48
B3	555.9	100	10350	132.25	26	117.32

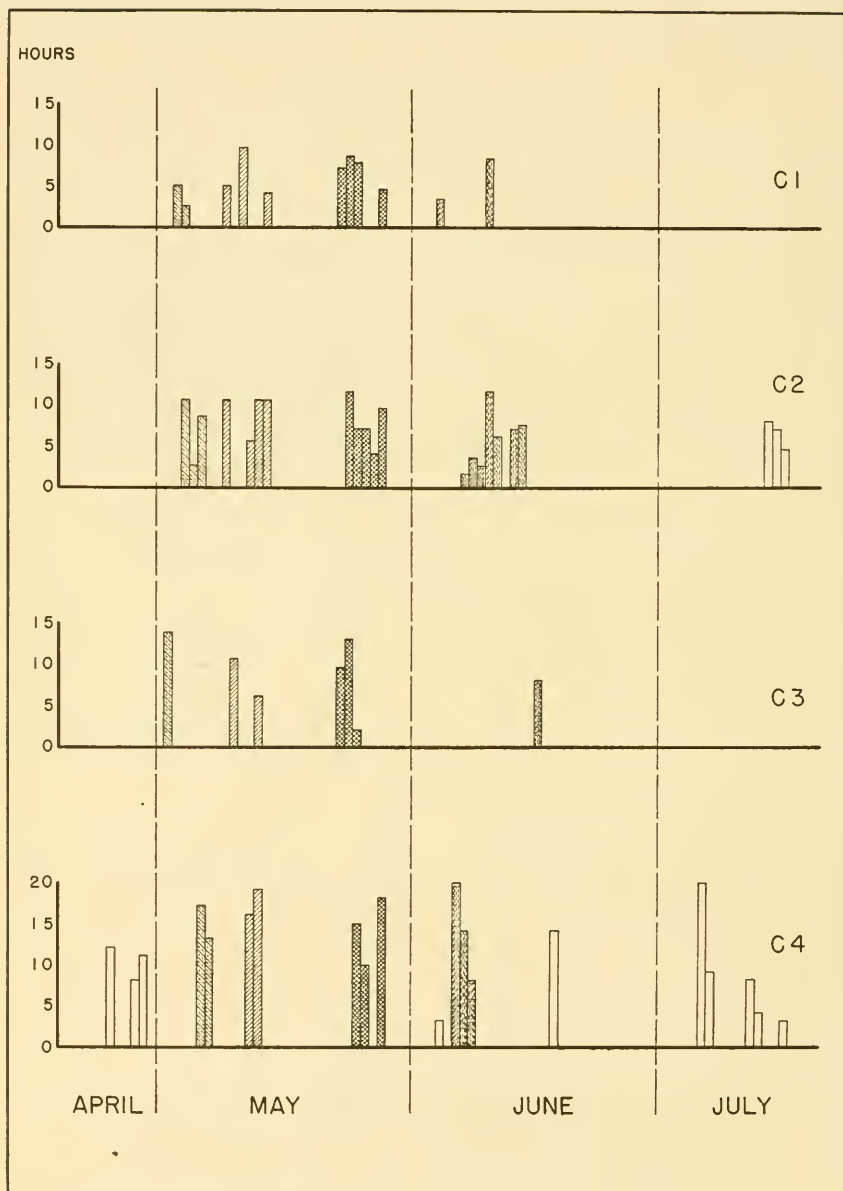


Figure 11.—Seasonal spray schedules on four farms which obtained fair control

FAIR CONTROL

The four-spray schedules, *Figure 11*, on page 16, illustrate the spray programs of individual farms that secured fair to good commercial control. All farm operators applied the four major sprays, one put on late maggot spray, and one operator applied three additional sprays.

Farm C1

This is a small low-yielding orchard. A small horse-drawn 100-gallon sprayer and a crew of two men were used in putting on four applications. A total of 59 hours were required in applying 6350 gallons.

Farm C2

This small orchard of 200 trees consisted mostly of two plantings; the largest block being 20-year-old trees, the other of 35-year-olds. The 11,650 gallons were applied in 150½ hours by means of a small one-man crew. The orchard was a minor enterprise on this farm and spraying had to fit into the operator's total schedule more closely than on other fruit farms. He applied five moderately heavy sprays. Seventy-seven gallons were applied per machine hour. The calyx spray was applied in 37 hours.

Farm C3

Farm C3 is a small orchard. Seventy-four of the 400 trees were over 30 years old and a large proportion of the others were seven to 10 years old. A two-man crew was used in operating a small 100-gallon-tank outfit. The 2950 gallons were applied in 32½ hours. Thirty-five gallons were used per mature tree equivalent.

Farm C4

Farm C4 is a small scattered orchard. Some of the trees are difficult to get at on account of rocks and rough topography. In the case of shifting winds it is almost impossible to get into position to cover adequately all parts of each tree. This is a very good example of the effect of poor site condition on the control of scab and pests. About 130 trees were over 30 years old. A two-man crew, using a 150-gallon-tank outfit, applied 11,255 gallons in 124 hours. Seven moderate applications were used. Twenty-one hours were required to apply the calyx spray. From the point of view of control, this operator was handicapped by location of orchard and by the large number of old trees. This makes it difficult thoroughly to protect the trees even with a large number of sprays.

Table 3—Data on Orchardists C1, C2, C3, C4 for 1932

No.	Mature Tree Equivalents	Size of Sprayer Gallons	Amount of Spray Season Gallons	Machine Hours Season Hours	Machine Hours Calyx Hours	Spray Material Cost Season Dollars
C1	177.1	100	6350	58.75	26.25	45.91
C2	239.3	100	11650	150.5	37	84.81
C3	376.4	100	2950	32.5	12.25	35.54
C4	264.5	150	11235	124.	21.5	113.33

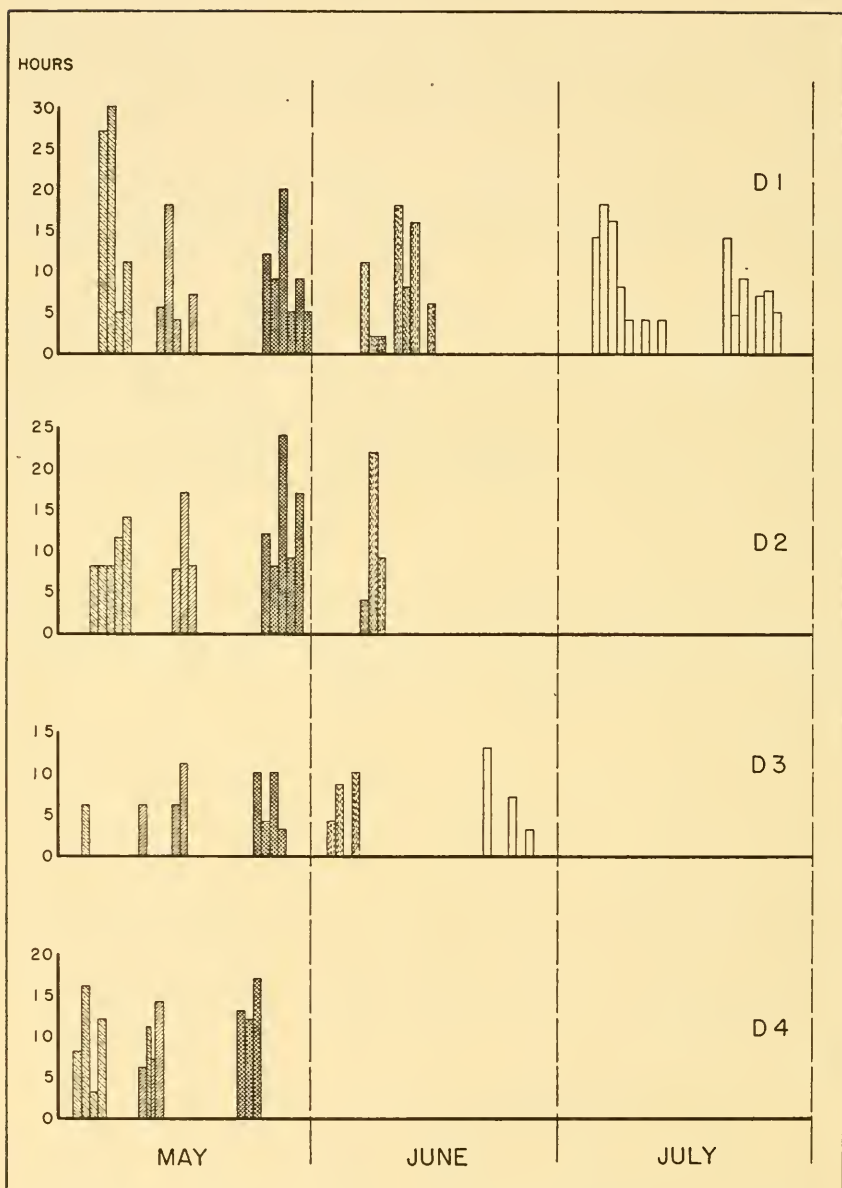


Figure 12.—Seasonal spray schedules on four farms which obtained unsatisfactory control

UNSATISFACTORY CONTROL

The four-spray schedules, *Figure 12*, on page 18, indicate spray programs on individual farms that failed to secure satisfactory commercial control. The four major sprays were applied, except in one case where the first cover was omitted. One operator applied one additional spray, and another, two additional sprays.

Approximately half of the trees on farm D1 are between 30 and 60 years of age. Six sprays were applied. A two-man crew operated a 150-gallon-tank outfit and applied 16,875 gallons in 197 hours. About 30 gallons of spray were used per mature tree, a higher application than most of the other operators used. The chief difficulty in this orchard is that of adequately covering the large old trees. The operator might do a better job with new equipment and more pressure and more care but even then he would be somewhat handicapped by the age and size of the trees.

Farm D2 is a mixed-age orchard, 37 trees being over 30 years old. A two-man crew and a 200-gallon outfit were used in applying 7800 gallons of spray in 100 hours. Four years later 8300 gallons were applied in 63 hours, indicating a marked decrease in time. In the four sprays a total of 24 gallons was applied per mature-tree equivalent. The fieldman's observations indicate that the operator was not thorough in getting the entire tree adequately covered. A check on the orchard showed that spray was not well distributed over the trees. The spray material cost 4.5 cents per box of apples (expected yield).

Farm D3 was a small orchard of 560 trees but equivalent to only 133 mature trees. There were a few trees over 30 years old. The 5700 gallons of spray were applied in 50 $\frac{3}{4}$ hours by a two-man crew operating a small 100-gallon outfit. Forty-three gallons were applied per mature tree equivalent.

Farm D4 was a small young orchard. All the bearing trees were between eight and 11 years old.

Three sprays, totalling 2650 gallons, were applied in 59 $\frac{1}{2}$ hours by a two-man crew operating a 100-gallon-tank outfit. Only 10 gallons were applied per mature tree equivalent. Since this orchard consisted wholly of young trees the opportunity of giving it adequate protection was a favorable one. This orchard is in a frost pocket and the crop is usually light. On this account, the operator did not feel justified in taking time from the other activities to spray adequately.

Table 4—Data on Orchardists D1, D2, D3, D4 for 1932

No.	Mature Tree Equivalents	Size of Sprayer (Gallons)	Gallons of Spray	Season Machine Hours	Calyx Machine Hours	Spray Material Cost (Dollars)
D1	563.2	150	16875	196	39	109.78
D2	321.6	200	7800	100	35	88.30
D3	132.9	100	5700	50.75	13.5	66.10
D4	261.7	100	2650	59.5	21	25.63

LABOR AND SPRAY MATERIALS REPORT

ABBREVIATIONS

Liquid Lime Sulphur = LS
 Dry Lime Sulphur = DLS
 Lead Arsenate = Lead
 Calcium Arsenate = Ca
 Nicotine Sulphate = Nic
 Oil Emulsion = Oil
 Spreader = Sp.
 New Jersey Dry-Mix = DM

Farm of W. P. MACK and SonDate MAY 4 19 32Day of Week WEDNESDAY

	Spray Material	Formula per 100 gal.	Field	Variety Sprayed or Dusted	Number Tanks Liquid Spray or Pounds of Dust	Number	
						Men	Horses
Midnight 12.00					GALS		
A.M. 12.30							TRACTOR
1.00							
1.30							
2.00							
2.30							
3.00							
3.30							
4.00							
4.30							
5.00							
5.30							
6.00							
6.30							
7.00							
7.30							
8.00	LEAD ARSENATE	3	ADAMS	ALL	800	3	3
8.30	LIME SULPHUR	2	ORCHARD				
9.00							
9.30							
10.00							
10.30							
11.00							
11.30							
Noon 12.00							
P. M. 12.30	← NOON HOUR →						
1.00							
1.30							
2.00							
2.30	SAME	SAME	ADAMS	ALL	600	3	3
3.00			ORCHARD				
3.30							
4.00							
4.30							
5.00	← SUPPER AND CHORES →						
5.30							
6.00							
6.30							
7.00							
7.30							
8.00							
8.30							
9.00	SAME	SAME	CEMETERY	ALL	1000	2	2
9.30			ORCHARD				
10.00							
10.30							
11.00							
11.30							
Midnight 12.00							

Remarks

Repairs—

Spray Application—

Gas and Oil—

A sample record for one day

Efficiency of operation

Spraying on the 40 farms was not an identical task. (Figure 13.) The number of sprays varied from 4 to 11 and the gallons applied ranged from 10 to 50 gallons per mature tree equivalent. The equipment ranged from small horse-drawn 100-gallon tanks to large 350-gallon, high-pressure, tractor-drawn outfits. In addition, the hill orchards some distance from the buildings, and without a near-by water supply, represent special difficulties as compared to the orchard on level land, near the buildings.

Since the tasks and the actual work done are so different on the various farms, no one measure gives an adequate comparison. However, three measures — namely, (1) gallons of spray applied per machine and per man hour, (2) the machine hours and man hours used in spraying per mature tree and (3) the machine and manhours used in applying the calyx spray per box of apples, give an indication of the differences in efficiency.

The gallons of spray applied per machine hour ranged from 45 to over 300. This includes the refilling and travel to and from the orchard as well as the actual application. The variation in gallons of spray applied per machine hour (*Figure 14*) was from 45 to 122 for the small, 126 to 200 for the medium, and 162 to 308 for the large machines, with averages of 86, 153, and 239 respectively.

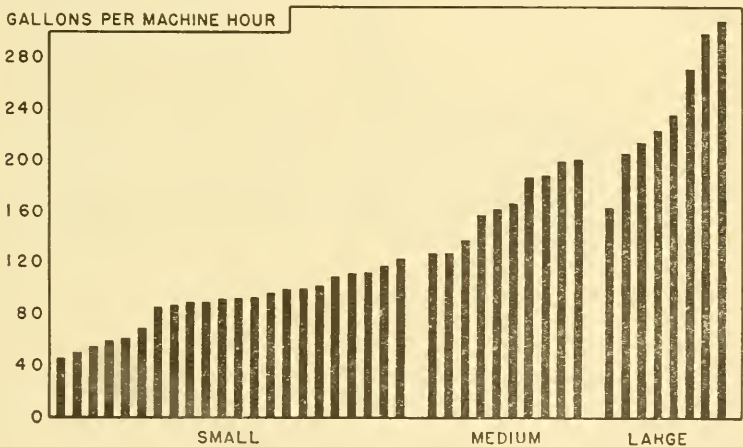


Figure 14.—Average total gallons of spray used per machine hour by small, medium, and large machines

The gallons of spray applied per man hour ranged from 22 to 145 (*Figure 15*). The variation was from 22 to 88 for the small, 52 to 111 for the medium, and 74 to 144 for the large machines, with averages of 49, 86, and 105 respectively.

The time required to apply spray per mature-tree equivalent is a practical comparison between farms since the age of the trees was taken into account in estimating the size of the orchards. With this measure, also, the range in machine use and man labor required varied widely on the 40 farms as indicated in *Figures 15 and 16*.

Since yields vary from year to year in the same orchard and also between orchards, for comparison the man hours and machine hours were related to the expected normal yield for each orchard. Twenty-three of the 40 operators used less than .04 machine hours per bushel, 11 used between .04 and .08 hours, and eight were over .08 machine hours per bushel. The man hours required followed a similar curve since two-men crews represent the usual combination. Seventeen of the operators used between .04 and .08 man-hours' spraying per bushel. Seven

used less and 16 more than this. The five highest used over five times as much man labor as the five lowest. When calculated according to actual yields, the average use of machines and man labor per bushel was less but the differences were more extreme.

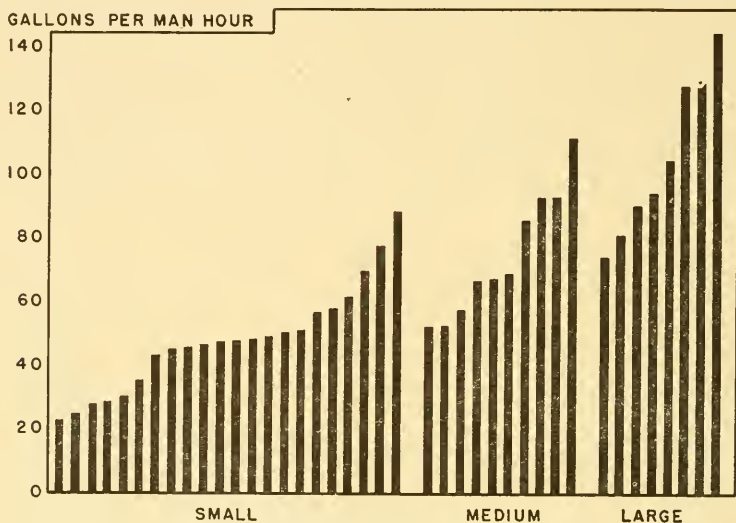


Figure 15.—Average total gallons of spray used per man hour by small, medium, and large machines

Since spraying is the chief operation prior to harvest time in this competitive commercial business, the variation in efficiency as indicated above are indeed very wide. For instance, one outfit actually applied more than seven times as much spray per hour as the lowest. Commer-

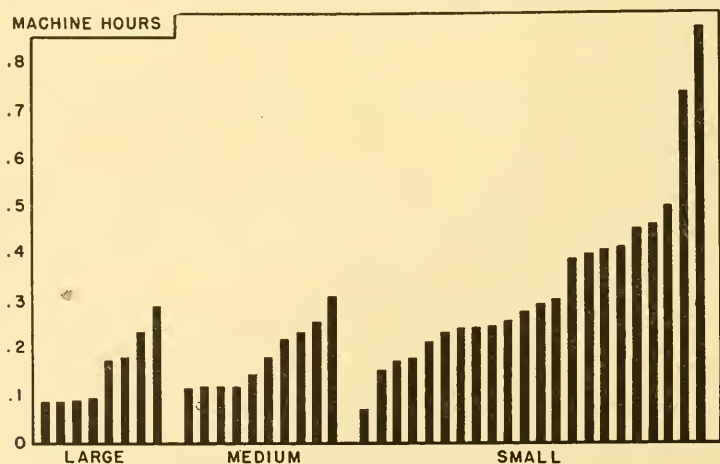


Figure 16.—Average season machine hours per mature tree equivalent by large, medium, and small machines

cial apple production on a specialized scale has been underway for at least a generation and, in general, the objectives in spraying for control of pests and diseases are similar on all farms; yet the cost in terms of the three general measures of efficiency indicate no common pattern. The data indicate that even with approximately the same size of spray outfit the variation in amounts of spray applied varies considerably.

The chief factors which determine the gallons of spray applied per man hour and machine hour are:

1. Size of crew
2. Topography
3. Water Supply
4. Capacity of tank, pump, and nozzle
5. Size of trees and spacing
6. Type of spraying procedure
7. Psychology and personnel of operators

The size of the crew affects the number of gallons of spray applied per machine hour and per man hour. One-man crews with medium-sized or small-sized machines are able to apply more gallons of spray per man hour than two-men crews — and two-men crews, more than three-men crews. For instance, one grower, in 1933, with a medium-sized machine, reduced his spraying crew from two men to one man and increased the gallons of spray per man hour from 99 to 158. Another grower with a small machine reduced his crew from three men to two men and increased the gallons per man hour from 34 to 47. However, the reduction in the crew resulted in a decrease in the gallons of spray per machine hour. In the two cases mentioned above the change from a two- to a one-man crew resulted in a loss of 20 per cent in the application per machine hour and the change from a three-man to a two-man crew resulted in the loss of eight per cent in gallons per machine hour. The larger number of gallons applied per machine hour by some of the two-man crews is due to continuous operation of a large capacity nozzle which was possible on account of the level orchard site and the practice of spraying closely set uniform trees, one side at a time, while riding past on the tank. With some three-man crews, spraying from the ground, it is the usual practice to spray all around a tree in one operation. Since the nozzle must be shut off while the man is traveling from one side of the tree to the other, or to another tree, such a practice results in intermittent spraying and decreases the efficiency of both man and machine. So the influence of the size of the crew depends somewhat on the procedure and method of spraying. A two-man crew may be as effective as a larger crew if large multiple nozzles are used on a compact orchard.

The topography of the orchard site has considerable influence on the spraying operations. It is important in determining the method of spraying, whether from the rig, or the ground, the number of men in the crew, the way the machine is to be drawn, and the size of the machine and nozzle. One orchardist operating a medium-sized pump with a two-man crew on a rough site applied 65 gallons of spray per man hour while another grower, using a one-man crew on a level site, applied 158 gallons per man hour.

On a very steep hillside, a full tank may not be drawn to advantage and, in addition, the trees tend to be low on one side of the spray rig and high on the other. It is more difficult and takes more time to cover the tree. A few of the orchards have wet areas in the early spring and considerable time is lost with the large outfits because of the traction.

The water supply affects the efficiency of both the labor and the machines. Any arrangement which permits quick filling in handy locations is all that is required. Growers with good tank fillers and conveniently located brooks or ponds in or near the orchard are able to apply as many gallons per man and machine hours as those who are equipped with stationary, overhead water tanks. The lack of water supply at the right locations, inadequate facilities for pumping or loading, and travel to and from the water supply were important items of time loss in some orchards. More careful planning of the route taken by the spray machine could save some travel and time in several orchards.

In two instances records and observations were made concerning the practice of transporting water or spray mixture to the sprayer by means of a "supply" tank mounted on a truck, thus saving some time of the expensive spray outfit by eliminating travel of the sprayer back and forth from orchard to the water supply.

In one orchard, spraying was done with a small 100-gallon-tank machine of a pump capacity of six to seven gallons per minute. Operating in 1934 without the supply tank, a total of 8700 gallons were applied at an average rate of 79.6 gallons per machine hour or 39.8 gallons per man hour. In 1935, using the supply tank, a total of 20,200 gallons were applied at a rate of 129.4 gallons per machine hour, or 41.7 gallons per man hour. It appears, that the use of the supply tank did not increase the efficiency in man labor materially, but that by increasing the output of the machine about 62.5 per cent it made it possible to cover the orchard in a considerably shorter time. Timeliness is an exceedingly important factor in disease control. In this case the additional man and the portable tank enabled the operator to get along a few years longer with his small machine.

In another orchard, a larger 300-gallon-tank machine of 25 to 30 gallons per minute capacity was operated. In the early season sprays, filling from waterholes in the orchard, 21,000 gallons were applied at the rate of 280 gallons per machine hour or 93.3 gallons per man hour. In the later applications, using the supply tank, 30,635 gallons were applied at the rate of 402.9 gallons per machine hour, or 100.7 gallons per man hour. This indicates a slight increase in labor efficiency. Furthermore, late in the season, the waterholes had dried up and the efficiency without the supply tank would have been lower than in the early part of the season.

Records in both orchards seem to show that carrying the water or the mixed spray materials to the tank is advantageous chiefly as a means of speeding up operations when quickly coverage is needed to protect against disease. From the point of view of economy of operation, providing wells or water holes in the orchard or constructing a system of supply tanks about the orchard is more desirable than using extra trucks.

With rough topography and small orchards, the medium-sized machine appears to be the most efficient for most orchards under New

Hampshire conditions. It delivers a sufficient quantity to supply a 6 to 8 nozzle spray rod, and is large enough to cover several hundred bearing trees in three or four days. Considering man labor only, the small machine requires 75 per cent more labor to cover the same orchard as compared with the medium machine — an average of 2.0 hours per 100 gallons applied as compared to 1.1 hours. Large machines resulted in greater labor efficiency than the medium-sized ones.

The data indicate that the medium machines will cover 78 per cent more trees than the small machine and the large machine 44 per cent more than the medium one in the same length of time. The proper size of machine to own depends upon the size and topography of the individual orchard. The large spray machine requires tractor power and can be used to advantage only where the topography is favorable and the orchard is large. Only a few orchardists are in a position to utilize advantageously the very large sprayers.

The size of the crew to employ will depend upon the time available to cover the orchard as well as the availability and cost of labor. The time available will vary with certain sprays and also the weather. Early in the season, when the delay of a few hours may mean the difference between success and failure in control of scab, a grower may find it necessary to operate the maximum crew in order to obtain the greatest efficiency out of the machine and cover the orchard in as short a time as possible. The cost of man power at such times is not important. With the cover sprays, applied primarily for the control of insects, the need to cover the orchard quickly is not so important and during this period smaller crews may be employed. Thus, early in the season, the important item is to get the applications on at the right time. Late in the season the most economical combination of machine and size of crew can be employed.

Obviously, if measured in gallons per hour, both man and machine efficiency are greatest when trees are reasonably large and not scattered, a condition which permits continuous operation of the nozzles. When spraying young trees which have been planted wide apart, the nozzle must be shut off while traveling from one tree to another and less spray is applied per machine and per man hour. Spacing young trees at permanent distance is a logical procedure where land is low in value but it does cost a little more per tree in terms of machine and man hours in spraying in the early period. When fillers are set, these additional trees require little additional time for spraying but, of course, they have only a few years of productive life. Practically all other costs, including that of spray material, is the same as for the permanents.

Because only a few tanks are required for each spray on small farms, the men have not felt it important to make special provisions for a quick method of filling the tank. On the other hand, on the large farms there is a definite rush to cover the orchard in time which is an incentive to speed up the spray operations. Thus, there is a different philosophy of management and use of labor on some of the small farms as compared to the large ones. In comparison, the large commercial orchardists must use equipment and man power to the limit in the spray periods.

Each orchardist must organize his spraying procedure in line with the size of his orchard and his available equipment and labor. The standards in *Table 5* are suggested as guides to help the orchardist in working out his procedure. These standards are based on the data from the 40 farms, but also take into account improved practices found on farms that are better organized. They are suggested as standards which should be accomplished under good management and under fairly favorable conditions. Real efficiency in spraying, of course, would be related to effectiveness of control and with the most economical combination of men and machines as well as size of machines.

COST OF SPRAYING

Material

There was considerable uniformity in the spray formulas used; therefore, a similarity in the cost of spray material per tree would be expected. However, because some operators used over four times as many gallons of spray as others, the cost varied greatly. Four orchardists reported less than two cents per bushel of apples (expected yield) while seven reported over six cents. Two who reported costs over 10 cents a box used special sprays. (*Figure 23.*) Based upon the data from the 40 orchards and the experience and recommendations of the Agricultural Experiment Station, it is thought that five to seven cents per bushel will furnish material for spraying.

The equipment

Because trees are growing in size and increasing in yielding capacity, the orchard is continually changing in size. In addition, some operators have filler trees and may take out many of these in some one year. Consequently, the spray outfit may be about the right size for an orchard one

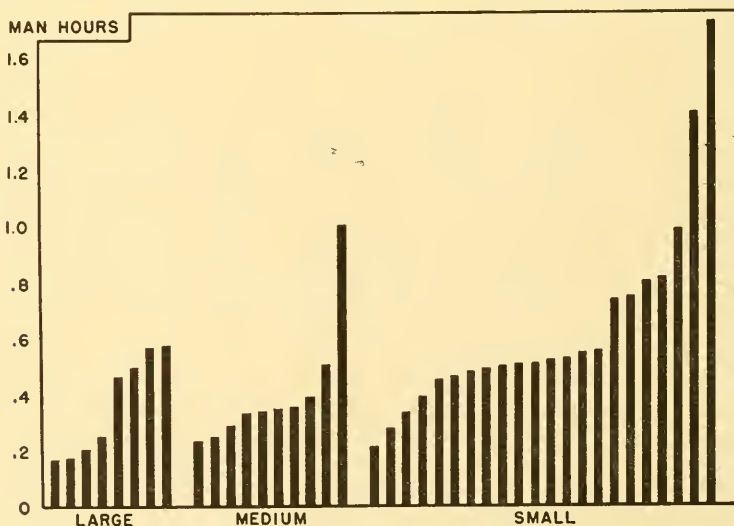


Figure 17.—Average season man hours per mature tree equivalent in spraying by large, medium, and small machines

year and more than inadequate the next. If an operator sets out 2000 permanent trees, he would probably get along the first two or three years with a small hand outfit. About two sprays would be sufficient. A small 100-gallon sprayer would be used from about the fourth year to the twelfth year when it would lack capacity to cover the orchard adequately and quickly. Thus, this sprayer might last eight years, being used at only part capacity at first and at full capacity at the end. At about the twelfth year a 200-gallon outfit might be purchased which would have sufficient capacity for the next five years when an additional sprayer or a larger one would need to be purchased. Even with the best of planning, it often happens that as the orchard grows spray equipment is not used to its fullest capacity for short periods.

Size of crew

The problem of whether to use a two-man or a one-man crew with a small machine — a two- or a three-man crew with large machines — may be one of convenience in getting the job done. If the sprayer is available on the farm and represents ample capacity to cover the orchard in the time available, the total cost associated with its operation will change very little if it is operated fewer or more hours per day. Whenever the investment in a spray outfit is made, much of the total cost is fixed and tends to continue whether or not it is used. The rate per hour will depend on how much it is used. (Its greater use would mean a declining rate per hour.)

In like manner, under actual operating conditions, if the labor is available on the farm, it is difficult to make best decisions by merely estimating the labor and machine cost at so much per hour.

Where wages are high and there is a large orchard area to cover, the large machines are very efficient in the use of man labor and tend to reduce the total cost. In addition, on account of the larger pumps and high pressure, the quality of the job is usually better. However, the difference in cost in operating medium-sized and larger sprayers is not sufficient seriously to handicap the grower with smaller machines. Some of the other costs are important and are not closely associated with size of the orchard.

From the records available, it is estimated that with a 100-gallon spray outfit and a two-man crew, .1 machine hours and .2 man hours will be required in the season per bushel of apples. The same outfit operated by one man, .14 machine hours, .14 man hours will be required. Two men cover the orchard in a shorter period and this may be the important consideration. On the other hand, if the orchard is small and extra labor is scarce, the operator might well spray alone.

The estimates of costs on seven combinations in *Table 5* are based on arbitrary assumptions of 40 cents per hour for man labor and \$1.50, \$2.00, \$2.50, and \$3.50 respectively per hour for the use of 100-gallon, 150-gallon, 200-gallon, and 300-gallon outfits. These assumptions would require that the size of the sprayer was well adjusted to the size of the orchard and would be used near capacity, and, in addition, that men were available for spraying at a definite wage whenever needed. (*Table 5.*)

Table 5

This table shows estimated costs of spraying with varying combinations of outfits and crew. The estimates are based on arbitrary assumptions of hourly cost rates for machines and men. (See text.)

Combination Number	Size of Tank	Number of Men	Estimated Cost of Machine per box Cents	Estimated Cost of Man Labor per box Cents	Estimated Cost of Machine and Man Labor per box Cents	Estimated Cost of Spray Material per box Cents	Estimated Cost of Spraying per box Cents
1	100	2	15.	8.0	23.0	.07	.30
2	100	1	21.	5.7	26.7	.07	.34
3	150	2	16.3	6.3	22.6	.07	.30
4	150	1	25.	5.0	30.0	.07	.37
5	200	2	13.7	4.7	18.4	.07	.25
6	300	2	15.	3.0	18.0	.07	.25
7	300	3	12.5	4.0	16.5	.07	.24

Cost of an additional spray

One of the important decisions which orchardists face each year is the application of additional sprays. For instance, an operator may plan to apply his usual five sprays but conditions may arise in July that show a need for another spray. He balances the result to be expected against the cost of the additional spray. But what is the cost? There is no easy blanket answer. Much depends on the other demands for labor and power on individual farms and the amount of actual cash cost.

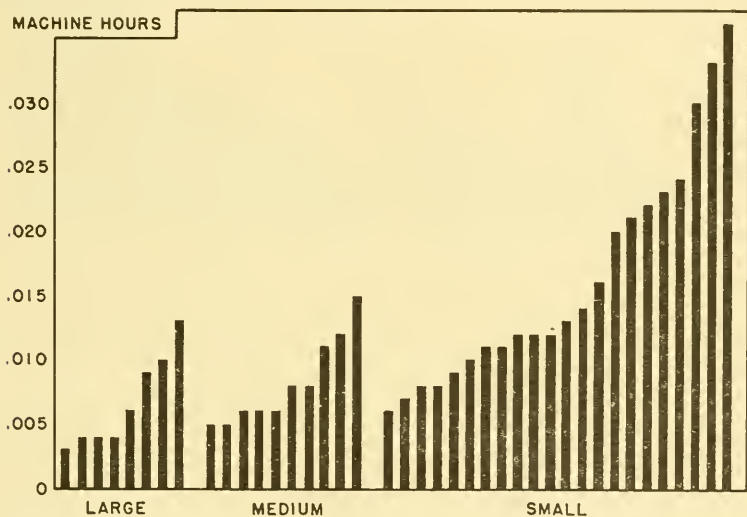


Figure 18.—Average calyx machine hours per bushel expected yield used with large, medium, and small machines

Since all operators apply the calyx spray to all trees and use approximately the same formulas with the same objective in view, the data concerning this spray are taken as a basis for discussion of the application of an additional spray. The distribution of the 40 farms according to machine hours and man hours required for calyx application is shown in *Figures 18 and 19*. The cost of the materials varied greatly on the 40 farms (*Figure 20*), but 1.2 cents for material for one spray per box of apples is estimated as sufficient for one application. Based on these data it is estimated that the orchard would be adequately covered by one spray with the expenditure per box of apples approximately as follows:

Estimated cost of machine	2.7 cents
Estimated cost of man labor	1.0 cents
Estimated cost of material	1.2 cents

	4.9 cents

However, under the usual orchard conditions, the chief out-of-pocket cost of the additional spray may be the spray material. This would depend on the situation in the individual orchard. From the viewpoint of the cost of the additional spray, the available help and the equipment tend to become fixed cost factors, especially on the family-

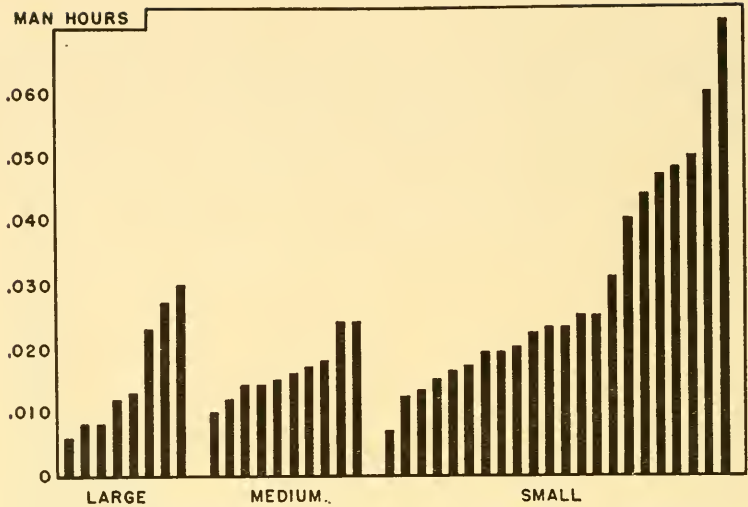


Figure 19.—Average calyx man hours per bushel expected yield

sized, specialized fruit farms. The spray machine will last about as long if an additional spray is applied, and the men and horses or tractors may not have other productive alternatives at this period.

Thus, on farms that have the equipment to apply spray efficiently, the additional cost of a marginal spray is very small. The decision as to the application of a spray should be based on a comparison of marginal returns expected in better quality of the fruit and the marginal costs. On some farms the extra cash costs would be largely spray materials.

On this basis, the orchardist with available labor and equipment could afford to put on the additional spray if he estimated it would tend



Figure 20.—Distribution of farms according to cost of calyx spray materials per box of apples (normal expected yield assumed)

to raise the value of his crop a few cents per box. If he had other high value uses for his available help and for a portion of his equipment, the cost of the "marginal" spray would be higher. The returns expected from the spray would have to be more substantial to make its application economic.

Some of the producers are omitting one or more of the generally accepted sprays. Since the application of the one spray reduces the actual cash out-of-pocket cost on specialized farms only about one and one-half cents per box of apples, its elimination is not advisable if there is a substantial risk in loss of quality.

On the basis of assumed rates of wages and costs per hour of use of spray outfits, the cost of an additional spray would be about five cents per box of apples. This is estimated on the basis of a normal yield. Thus, on farms where all these cost items should be included in the application of an extra spray, the expected returns from it must average at least five cents per box to justify it. Should the yield be higher the normal cost would be less per bushel. But should the yield be lower than normal, the costs per bushel would be greater.

Should some other productive use of the man power be in great demand at the specific spray period, it is possible that the operator would need at least 10 cents return from the extra spray bushel of apples to induce him to leave other tasks to apply it. However, the combination of farm or other enterprises in which some essential practice competes too seriously with normal spray period is questionable. Over the long period, spray must be applied adequately and at the right times if the orchardist is to succeed.

Other Studies in Economics of Apple Orcharding include

- I. An Apple Enterprise Study — Costs and Management (Bulletin 257)
- II. A Study of Farm Organization on 12 Fruit Farms (Bulletin 279)
- III. A Study of Orchard Problems by the Budget Method of Analysis (Bulletin 323)



